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Geothermal energy in Australia

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Although Australia is not usually associated with geothermal energy, it possesses significant amounts of both conventional (wet) geothermal and hot dry rock (HDR) geothermal resources. The country's conventional geothermal resources are extensive, but are low temperature and are located in areas of low population density with the result that they are not used extensively for either electricity generation or for direct heating. Australia's HDR resources, on the other hand, represent a world-class resource but have not been used to date because the technology for converting HDR resources into electricity is not yet fully commercial. The effort being directed towards exploring economically useful HDR resources and in the development of technology to convert this energy resource into electricity could make HDR resources an important part of Australia's energy mix in the near future, but there are major barriers.

Keywords: Geothermal power; Hot dry rock (HDR); Energy resources

Introduction

Geothermal energy is produced by radioactive decay occurring within Earth's interior and from crustal plate movements. It is a finite energy source and, although not technically renewable (cf. wind and wave power), is a very large, naturally occurring resource that can be converted to electricity or used directly for heating without causing pollution.

Conventional geothermal electricity generation plants use steam from geysers or from superheated ground water in those locations where the geothermal resource is close to Earth's surface, which is usually near the edges of tectonic plates. The Australian continent, however, is located well within a tectonic plate and is not within a region of intense tectonic activity. The most recent volcanic activity is thought to have occurred in the Mt Gambier region of south-eastern South Australia approximately 4500 years ago [1]. The country therefore does not display the usual highly visible signs of geothermal energy, such as geysers and is therefore not usually associated with geothermal energy [2].

Despite the lack of overt signs of geothermal activity, Australia does possess extensive conventional geothermal (wet geothermal or hydrothermal) resources, and hot dry rock (HDR) geothermal resources. The existence of these large geothermal resources is due to a unique feature of Australia's geology, an abundance of high temperature granite occurring at depths

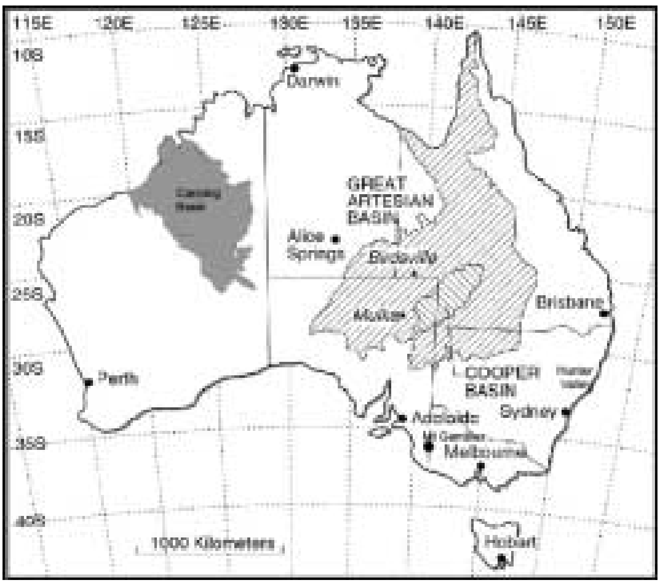

Figure 1. The Eromanga (Great Artesian) Basin (adapted from [6]).

of less than 5 km and covered by water-bearing sedimentary layers that act as effective thermal insulators that keep the granite at twice the usual temperature of granite at such depths. Approximately 80% of these geothermal resources are thought to be located in the Cooper Basin and the overlying Eromanga (Great Artesian) Basin [3]. The latter basin, the largest artesian basin in the world, extends from Cape York and the Gulf of Carpenteria (Queensland) in the north to the north-western region of New South Wales and central South Australia in the south (figure 1).

The use and status of these two geothermal resources are discussed below, together with a brief summary of the use of shallow sub-surface ground heat as an energy source for electric heat pumps.

Geothermal heat pumps

Close-to-surface ground heat, which is used as a source for electric heat pumps, is a genuine renewable source of energy as it is replenished by incoming solar radiation. The Australian geothermal heat pump (GHP) market, however, is very small due to the relatively low electricity and natural gas prices in Australia, combined with only moderate space heating loads [4]. The number of systems installed by 2001 was estimated to be approximately 2000 units, with the total installed capacity in 2001 estimated to be 24 MW and an average size of 12 kW [5]. Although very small, the market is growing rapidly and total installed capacity is thought to be increasing at a rate of approximately 50% p.a. [6].

Geothermal aquifer resources

Australia's conventional, or wet, geothermal resources occur over a large area. These resources are not used significantly to generate electricity, however, as they are a low temperature resource (30°C to 100°C) and occur in areas of low population densities. Only two conventional geothermal systems have been constructed in Australia to date and both are small-scale units using low temperature hot water from the Great Artesian Basin to generate electricity for remote settlements.

A small geothermal power station exists in the small remote township of Birdsville in south-western Queensland. The system was installed in the early 1900s and uses water from the town's artesian bore, which produces about 30 L/s of 99°C water at a shut-in pressure of 1213 kPa from a depth of about 1200 m. Due to design problems, the system operated with a service factor of only 50% and a cycle efficiency of 4%. It was unable to meet the town's entire electricity load, which fluctuates between 60 and 150 kWe, except during periods of low demand [6]. With a grant from the Queensland Government, the system has recently been upgraded to increase its capacity and to convert the closed-loop working fluid to isopentane. The 150 kWe geothermal power station now operates as a demonstration plant and displaces approximately 160,000 litres of diesel a year, mitigating 430 t CO_2-equivalent.

The other geothermal power plant operating in Australia is a Rankine Cycle (Freon refrigerant) engine system installed in 1986 at a cattle station at Mulka in the remote north-east of South Australia. The 20 kWe binary flash-steam system used 85°C water from the station's artesian wells, making it the lowest temperature hydrothermal electricity generating system in the world [6].

Because it is a low grade and available only in central Australia, the geothermal resource of the Eromanga (Great Artesian) Basin has potential to supply only a relatively small number of towns located near to the resource. The total demand for power at sites where the resource is available has been estimated to be 20 MW [6].

Other geothermal aquifer resources closer to larger population centres are used as a source of energy. These tend to be lower temperature resources and are used only to a relatively small degree to provide direct heating.

The Glenelg Shire in Victoria has used hydrothermal resources for direct heating for over 15 years. A 1400m deep bore producing 58°C water at a rate of 90 L/s is used by the Shire to heat more than 19,000 m^2 of building space and a 2000 m^3 swimming pool. The total capacity of the facility is 10.4 MWt [6].

Several sedimentary basins in the Perth region of Western Australia contain aquifers which form an important water supply source in the region. The water temperatures are between 35° to 45°C and water from bores up to 1200 m deep has also been used to warm swimming pools and other facilities [7]. A direct geothermal heating system installed in 2004 at the largest aquatic centre in Australia, the Challenge Stadium, is one example and uses this source to heat 11,000,000 litres of water. The system is estimated to reduce expenditure on energy by approximately $200,000 per year and to reduce greenhouse gas emissions by some 1,250 t/yr [6].

Hot dry rock

Recognition that Australia is possibly one of the most geothermally prospective places on Earth came from observations by geologists that were published in the mid-1980s [7]. This was confirmed in the mid-1990s by a research group jointly funded by the Energy Research and Development Corporation (ERDC) and the Australian Geological Survey Organisation (AGSO). The study used temperature data from approximately 3500 boreholes to map the temperatures at a depth of 5 km. Based on this research, the total potential geothermal resource was estimated to be 2.5 million petajoules, or 7500 times Australia's total current annual energy consumption [8].

The early map constructed by Somerville *et al.* [8] was non-uniform as it was biased towards areas of oil and gas exploration activity. Researchers from the Australian National University (ANU) used temperature data from a further 1430 wells and a triangulated irregular network technique to estimate temperatures between boreholes. The results [2] verified that Australia has a significant geothermal energy resource and that regions of high crustal temperature at depths of less than 5 km could be economic targets for HDR technology.

Two other features of the Australian resource are important. The water and natural gas bearing sedimentary layers overlaying the granite are easy to drill through and the natural cooling of the granite over 20 million years created horizontal fractures. Pressurized water pumped into wells drilled into the granite causes these fractures to expand, creating horizontal reservoirs. The resulting horizontal reservoirs, with vertical injection and production wells, represent the optimal engineering combination, helping to make HDR a potential economic proposition in Australia [9].

A highly prospective HDR region located south of Muswellbrook in the Hunter Valley of New South Wales, contains approximately 75 cubic kilometres of granite rock at an average temperature of 250°C. The first HDR exploration tenement in Australia was granted to Pacific Power in February 1999. In the same year, the School of Petroleum Engineering at the University of New South Wales obtained a $1 million grant to build Australia's first geothermal test site in the Hunter Valley and demonstrate that heat mining was possible. A well was drilled approximately 1 km into the hot granite rock almost 4 km underground and hydro- fracturing techniques were used to create a reservoir with a volume of about one cubic kilometre. A second well was then drilled into the reservoir to complete the loop. A company formed by a consortium, Hot Rock Energy Pty Ltd (HRE), proposed constructing an initial $50M pilot project followed by a 10 MW power plant five years later with a long-term goal of constructing a 350 MW power station [6]. See figure 2.

A second company, Geodynamics Ltd (GDY), was registered in November 2000 by a consortium that included researchers from the ANU and floated on the stock exchange in September 2002. GDY subsequently acquired the patented Kalina Cycle heat to power conversion cycle technology and Pacific Power's HDR tenements in the Hunter Valley.

The ERDC study indicated that the most prospective region for HDR resources was in the Cooper Basin in north-eastern South Australia and south-eastern Queensland, which was estimated to contain approximately 1000 cubic kilometres of granite at a depth of 5 kilometres and a temperature of about 300°C. GDY spudded a well 10 km south of Innamincka in the Cooper Basin in February 2003, which was completed at a depth of 4421 m in October 2003 and the granite successfully hydraulically fractured. With the assistance of a $5 million grant from the Commonwealth Government, GDY has now drilled two wells 500 m apart, penetrating 700 m into the granite to assess the thermal gradients and heat exchange capacity. The only company to have proven its HDR resources, GDY is now constructing a pre- commercial 3–5 MWe plant in the central Cooper Basin that is expected to be online in 2007 and which the company hopes will pave the way for investment in a 200 MWe commercial plant.

A third prospective geothermal energy area is located in the Mount Gambier region in the south-east of South Australia. The area lies over a volcano that erupted some 4500 years ago and the region has high heat flow relative to the surrounding areas. Scope Energy Limited is undertaking a drilling program with the assistance of $3.9 million grant from the Commonwealth Government. The company hopes to prove that the resource is sufficient to run a 250 MWe plant and predicts that the costs of the electricity produced will be competitive with electricity produced from combined cycle gas-fired plant.

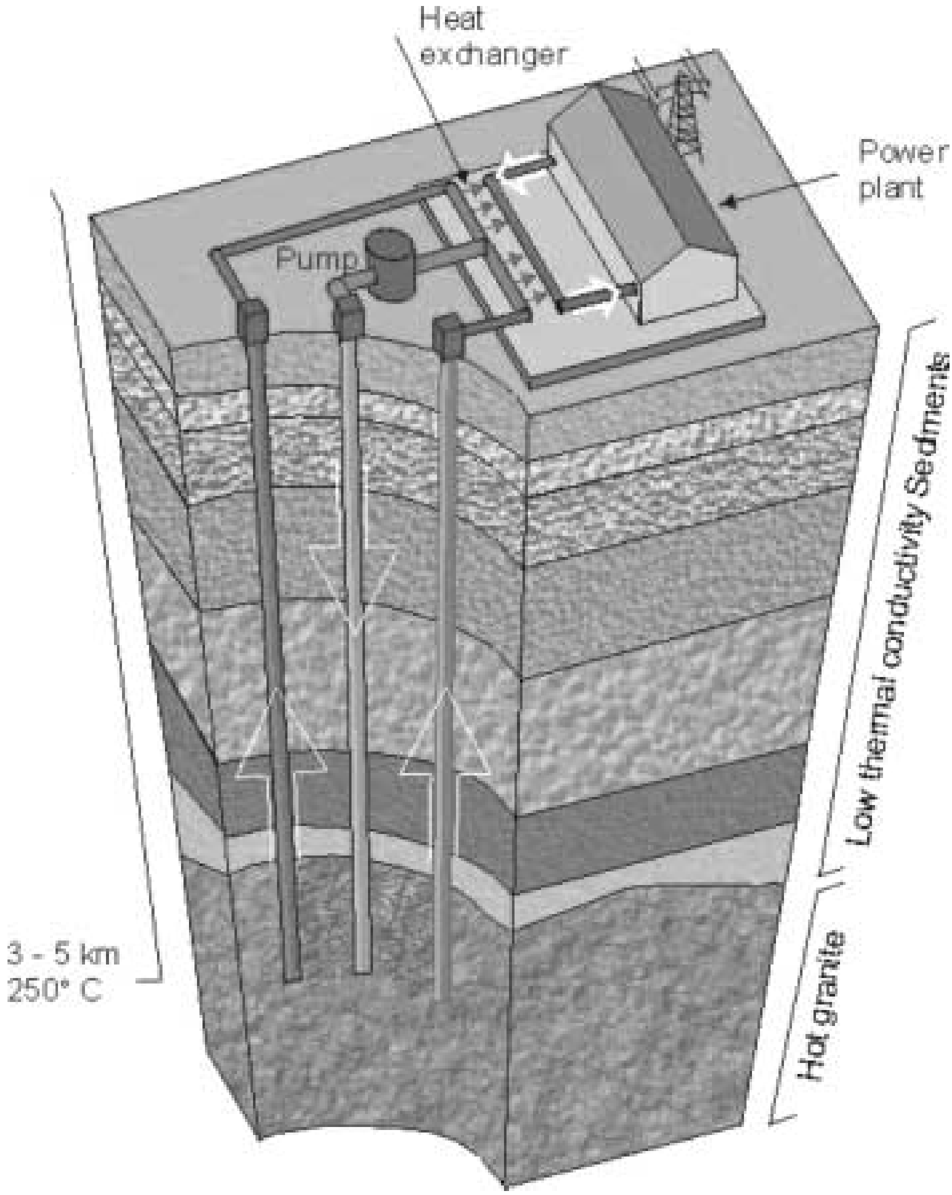

Figure 2. Hot Dry Rock technology (*source*: Hot Dry Rock program, Australian National University).

At least seven companies are now actively involved in geothermal exploration and most states either have enacted or are in the process of enacting legislation to govern geothermal (HDR) exploration activity. Over 65 geothermal exploration licences have been issued in South Australia alone. PetraTherm, in conjunction with the University of Adelaide, has developed a toolkit designed to assist in the location and evaluation of HDR resources and has reported finding high temperature gradients in shallow granite at sites close to the existing electricity grid and large mining operations [10]. Other companies have reported similar results [11].

Thermal mapping has identified a number of other prospective HDR basins in Australia, including the Canning Basin in northern Western Australia. The economics of HDR projects in Australia, however, are yet to be proven. Furthermore, while a number of companies are actively engaged in HDR exploration, the successful exploitation of those resources in some cases faces two significant challenges. The first is that the HDR resources in some regions, including the Cooper Basin, lie beneath significant natural gas deposits, and natural gas is currently the more valuable resource. Secondly, regions such as the Cooper Basin are very remote from major electricity or energy load centres. A solution to this, proposed by one company, has been to use the HDR energy resources in the region to produce hydrogen, mix the hydrogen with natural gas to produce hythane and transport the hythane to markets using the existing natural gas pipelines [12]. Not all HDR resources face these challenges and those in the Hunter Valley and the Mt Gambier region are located close to both electricity transmission infrastructure and major load centres, giving them a competitive advantage. The significant investment in the assessment of HDR resources and in the development of HDR technology also indicates that many investors believe that HDR technology has a promising future in Australia.

Conclusions

- Australia has vast geothermal resources, but these are largely unused at present due to their remoteness from major load centres and the costs of building major plants
- Currently, the main use of geothermal energy is as a heat source for heat pumps using superficial aquifers for heating and cooling and the direct use of hot aquifers for community heating projects.
- Hot dry rock is a major energy resource, but this resource has not been exploited due to the cost of producing electricity from it. Several pilot projects are underway in the Hunter Valley of NSW, and in the Cooper Basin and near Mt Gambier in SA.
- There is also an active program of geothermal resource exploration underway throughout Australia.

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